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FOREST FIRES IN PENNSYLVANIA

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A special fire-weather forecast on the afternoon of April 15, 1976, stated, "High forest fire danger over Pennsylvania and New Jersey. There has been little significant precipitation for some time over either State. Very low humidities of the past several days intensified this situation with resultant high fire danger. Since very little significant precipitation is expected for the next several days, the danger is not expected to lessen."

During the early afternoon of April 19, a weather observer near Haneyville reported northwesterly winds of 14 miles per hour, relative humidity of 24 percent, and fine fuel moisture of 3 percent. At 1:25 p.m. a primary electric line on the east side of highway PA-44 near Haneyville broke and ignited the fine fuels along the highway. Another fire, Wallis Run, started from burning debris on the same District 5 minutes before the electric line fell. Key personnel from the District Forester's office were enroute to this fire when they received the report from Haneyville.

The Haneyville fire spread rapidly, moving into oak stands where the oak leaf roller, oak leaf tier, and two-lined chestnut borer had caused extensive mortality. By 2:55 p.m. spotting was observed a quarter of a mile ahead of the main fire. The fire burned 3,330 acres before it was extinguished on April 21 and required the suppression efforts of 18 Forest Fire Wardens, 392 crew members, and 26 State Forest and Park employees. During the same period the Wallis Run fire burned 280 acres and required 166 suppression personnel plus men and equipment from 5 volunteer fire companies.

It is an unusual year when there are not at least 1,000 wildfires in Pennsylvania with an occasional Haneyville fire not uncommon. This fire load requires responsive fire management programs which are developed, in part, by evaluating fire and weather records. The following is such an evaluation, including an attempt to determine how the information might fit into an overall approach to the problem of protecting the forest from wildfire. Although conventional fire statistics are included, this investigation is mainly concerned with other types of analysis.

BASIC FIRE STATISTICS

A tabulation of Pennsylvania's fire activity is published annually by the State (Division of Forest Fire Protection 1977) and by the USDA Forest Service (1977). Summary statistics used in this paper were taken from these sources as well as from 1936-1974 punched-card data and 1914-1974 Pennsylvania office tabulations. The long-term data include number of fires, total acres burned, and cost of extinction. Extinction cost is what is actually spent to fight fires, not fixed, administrative costs. The punched-card data include fire cause, man-hours to control, damages, and individual fire size. Although these data make many statistical comparisons possible, we have

included only those that provide an interpretive base for management planning.

The long-term data show some interesting features. Number of fires is affected not only by weather and fuel conditions but also by prevention efforts (fig.la). The annual average number of fires decreased more than 50 percent from 1914 to 1974. This appears to reflect the modernization of the State fire forces which occurred in the mid-1940's and an increased emphasis on prevention.

Management factors are also evident in the long-term statistics of acres burned (fig. 1b) because the number of acres burned decreased expotentially. It was not unusual for hundreds of thousands of acres to burn during the early years, but only once after the mid-1940's did the acreage burned exceed 50,000 acres. Increased efficiency in suppression efforts is one of the reasons for this trend as evidenced by the steadily decreasing annual number of large fires (those greater than 10 acres) (fig. 1c).

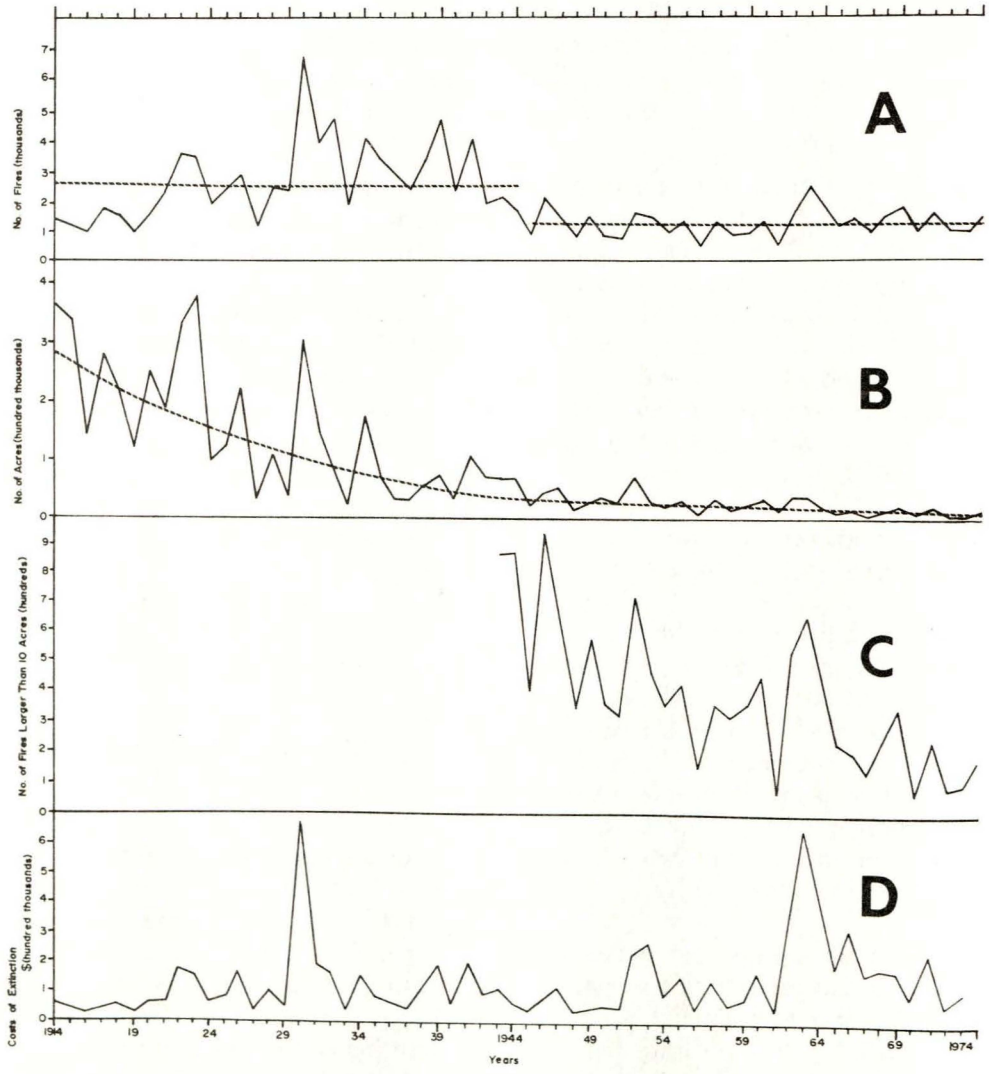

Figure 1.—*Four measures of fire activity: (A) Number of fires from 1914 to 1974. Dashed lines show the average for 1914 to 1944 and 1945 to 1974. (B) Number of acres burned from 1914 to 1974. The dashed line shows the trend with time. (C) Number of fires larger than 10 acres, 1942 to 1974.* (D) *Cost of extinction excluding fixed, administrative costs.*

The State's spatial distribution of fires shows the heaviest concentration in the forested east and south-central (fig. 2). Counties of major concern include: Franklin, Lackawanna, Luzerne, Northumberland, and Schuylkill. Except for Franklin, these are coal-bearing areas and have a long history of man-caused fires.

SEASONAL DISTRIBUTION OF FIRE DURING NORMAL, DROUGHT, AND WET YEARS

Some figures in this section are presented as percents of peak class. For the "peak class" method a value of 100 percent is assigned to the week of the year that had the most fires and then this value is used to calculate percentile values for the remaining weeks. This method normalizes the data so fire activity between different areas can be statistically compared.

Pennsylvania has been partitioned into climatic divisions that correspond to fire-weather forecast zones (fig. 2). Discussion in this and following sections concentrates on three climatic divisions that has high fire-incidence—the Pocono Mountains, Middle Susquehanna, and South Central Mountains.

The Normal Year

The fire distribution pattern of the Pocono Mountains division is typical for Pennsylvania and

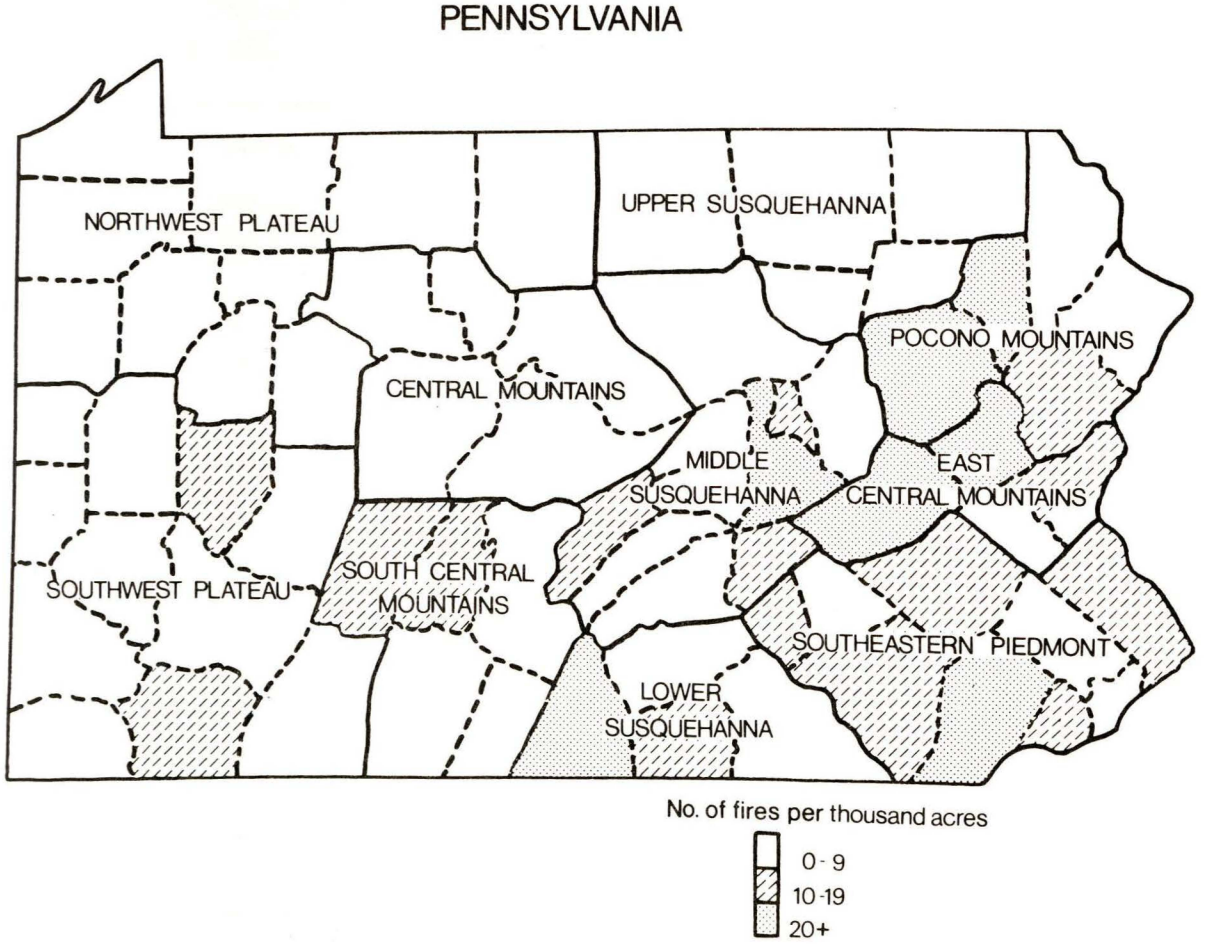

Figure 2.—*Average annual number of fires per thousand acres by county, 1970 to 1974. Also shows climatic divisions, which in most cases correspond with fire-weather forecasting zones.*

for much of the northeastern United States (fig. 3). Spring fire activity peaks in late April and autumn fire activity peaks in late October. If we define the beginning of the fire season as the week when fire numbers reach 10 percent of the greatest activity (Haines and Johnson 1975), then the spring season begins the third week in March and ends in mid-June; the autumn season begins in early October and ends in late November.

Other Pennsylvania divisions closely agreed with this same spring fire activity pattern, but differed somewhat for the autumn season. The Pocono Mountains division experienced fire numbers of 25 percent of the worst week of the spring season, but the Middle Susquehanna had an autumn week of more than 40 percent of peak week and the South Central Mountains had an autumn week that averaged 65 percent of peak week.

The peaks and valleys in fire occurrence are highly dependent on seasonal changes in weather, fuels, vegetation, and human activity. During April, the most severe fire month, incoming solar radiation is almost the same as it is during August. But hardwood forests are devoid of foliage in the spring so more solor radiation reaches litter and slash. Also in the spring there are more litter fuels due in part to slow shedding of dead foliage by some oaks. Spring is the time of year when deep low-pressure areas develop over the United States and produce extended periods of strong winds in Pennsylvania. Low humidities coupled with these strong winds make this season optimum for fuel drying.

In May the hardwood forest produces a leafy canopy that greatly reduces solar radiation at the forest floor. The humidity increases and wind-speed decreases. The change is especially

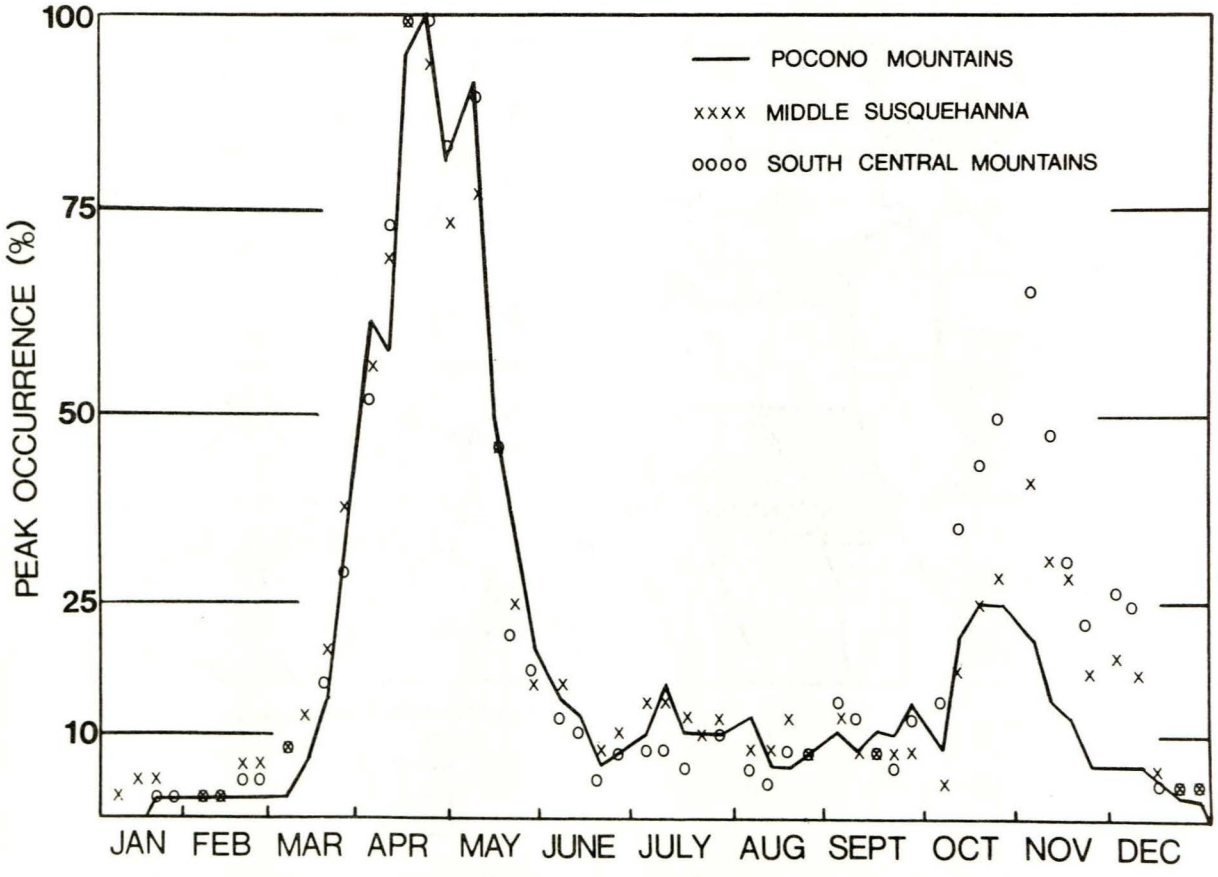

Figure 3.—*Number of fires during the average year for three climatic divisions, 1936 to 1974. Data are presented as a percent of peak occurrence. The week with the most fires is assigned a value of 100 percent with all other weeks assigned a percentage value relative to that week.*

apparent under the forest canopy. In summer, litter fuels decay rapidly and are at the annual minimum. During the summer the lower vegetation is also in full growth. Both the tree canopy and the lower vegetation create conditions that reduce the probabilities of fire ignition and spread.

As autumn approaches, the lower green vegetation begins to mature. Grasses and other herbaceous vegetation cure rapidly and in October and November a large portion of the canopy of hardwood leaves fall and become part of the surface fuels. The days are shorter and temperatures lower; therefore, burning periods are normally short and infrequent. During winter, surface leaves often dry to low moisture content, but the duff generally retains moisture so the few fires that start do little damage.

Drought and Wet Years

Meteorological drought is defined as a prolonged and abnormal moisture deficiency, and the severity of a drought is a function of moisture demand as well as moisture supply (Palmer 1964). Drought depends upon the local climate; for example, normal meteorological conditions in New Mexico would be regarded as drought-producing in Pennsylvania. Also, time must be considered as a drought factor because it usually takes many weeks or months for serious conditions to develop.

Forest fire potential can be gauged with the Palmer (Drought) Index. This Index evaluates the degree of drought on a numerical scale and can be correlated with such things as general crop conditions, water supplies in streams and lakes, and forest fire danger.

The Palmer Index is, by design, a slow response system most applicable to conditions in subsurface soil. It does not reflect the fire situation in spring when critical surface conditions are changing rapidly and subsoil conditions usually play a minor role in fire danger and fire behavior. This Index is applicable during summer and early autumn when deep burning, large fires are a significant threat in the northeastern United States (Haines *et al.* 1976).

During the period 1929 to 1963, Fieldhouse and Palmer (1965) found that within the climatic divisions of the State (fig. 2) the number of droughts varied from 29 in the Pocono Mountains to 42 in the South Central Mountains. Statewide, during these same years, the percent of months with indicated drought severity was as follows: Incipient, 11 percent; Mild, 18 percent; Moderate, 11 percent; Severe, 6 percent; and Extreme, 3 percent. This means that, on the average, moisture stress is evident almost 50 percent of the time, although most of these stress periods are not serious.

A drought is often geographically selective. For instance, the extreme drought of the mid-1960's did not affect all divisions of the State to the same extent. Drought was of concern in much of the forested region of the State, but it was a near disaster in the extreme east. The Pocono Mountains division was in some stage of drought from mid-1961 to mid-1969 (fig. 4) and did not enter a substantial wet period until the summer of 1971. This situation is reflected in the number of wildfires—301 wildfires in 1963 and 387 in 1964, the only years with more than 300 fires from the mid-1940's to present in that division.

An interesting feature of these drought periods involves the sudden taxing effect on the State's fire management organization. Cost of extinction, for example, increases dramatically (fig. 1d). The two extreme drought periods of the early 1930's and the mid-1960's stand out as unusually costly periods in relation to the rest of the record.

The month-to-month importance of drought to wildfires can be determined by statistically analyzing two measures of fire control. The first analysis shows drought's effect on the occurrence of fire as measured by fire-days[1] (fig. 5). Drought's impact on fire occurrence is strongly evident from May through September, therefore, continuous prevention efforts should be in effect during this period when drought dominates. The second analysis shows influence of drought on difficulty-of-control as measured by cost-to-suppress (fig. 6). Values are highest from April through October so droughts effects are most important during these months.

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[1] *A fire-day is defined as a day having at least one reported fire in the protected area.*

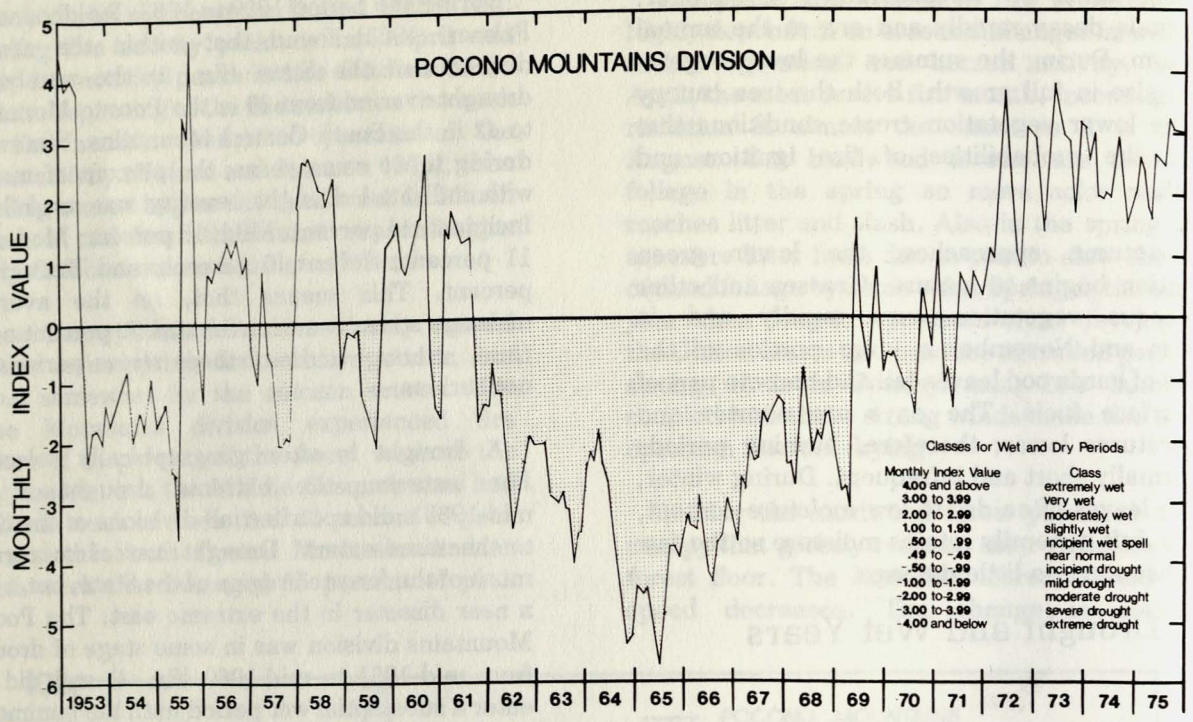

Figure 4.—*Monthly values of the Palmer (Drought) Index for the Pocono Mountains division, 1953 to 1975.*

Seasonal wet or dry periods will drastically change the yearly distribution of wildfires (fig. 7). During years with a dry spring followed by a wet fall there is a strong spring fire season and little fire activity in summer and autumn. But during years with a wet spring followed by a dry autumn the peak fire activity week will often occur in November and there may be heavy fire activity by early September. The wet early season produces abundant lower vegetation. In its lush green stage it acts as a strong heat sink and fire barrier. The dry late season changes this barrier into a fire carrier because of the large increase in dead fine fuels.

During years with a dry spring and fall the most distinct feature in the seasonal profile based on peak occurrence was increased fire activity during the summer as a percentage of peak spring class. During years with a wet spring and fall, there was no summer activity.

FIRE CAUSE

Weather, fuel, and vegetation stage are factors in fire danger but so are the attitudes and habits of people. As people's attitudes and habits change, so does the distribution of fires in the various cause categories. Campfires were the major cause of wildfire through the 1950's, however, part of this dominance may be due to reporting methods (table 1)—other factors such as smoking, which is now a separate classification, were formerly included under campfires. Nevertheless, the decline of campfires as the predominant cause of wildfire is impressive. In the 1930's, 64 percent of fires fell into the campfire category; today campfires account for only 3 percent of total. The decrease in these fires is mainly due to fire prevention efforts and changes in camping-recreation activity. In the 1930's camping often consisted of establishing an individual site to the best of the recreationist's abilities. This usually

included primitive cooking-fire arrangements. Today's modern campgrounds and fire sites have reduced this hazard (Creelman 1974).

Three other cause classifications—debris, railroad, and incendiary—also show interesting trends. Debris fires as a percentage of total fires increased slowly from the beginning of records through the 1950's, declined sharply in the early 1960's, and then rose rapidly again in the late 1960's (fig. 8). This upward trend may have been due to the clean-up activity of people who bought second homes and cottages. Since 1971, debris fires have again begun to decrease. This decrease seems to be due to : (1) trash pickup as a regular service of municipalities, (2) local ordinances regulating trash burning because of air pollution regulations, and (3) intensification of the "problem township program" (Creelman 1974). The "problem township program" was begun to reduce the number of fires in townships that had 10 or more fires per year for 5 or more years. A plan was designed for each township to reduce its number of fires. The plans differed depending on the specific causes of fires that were occurring.

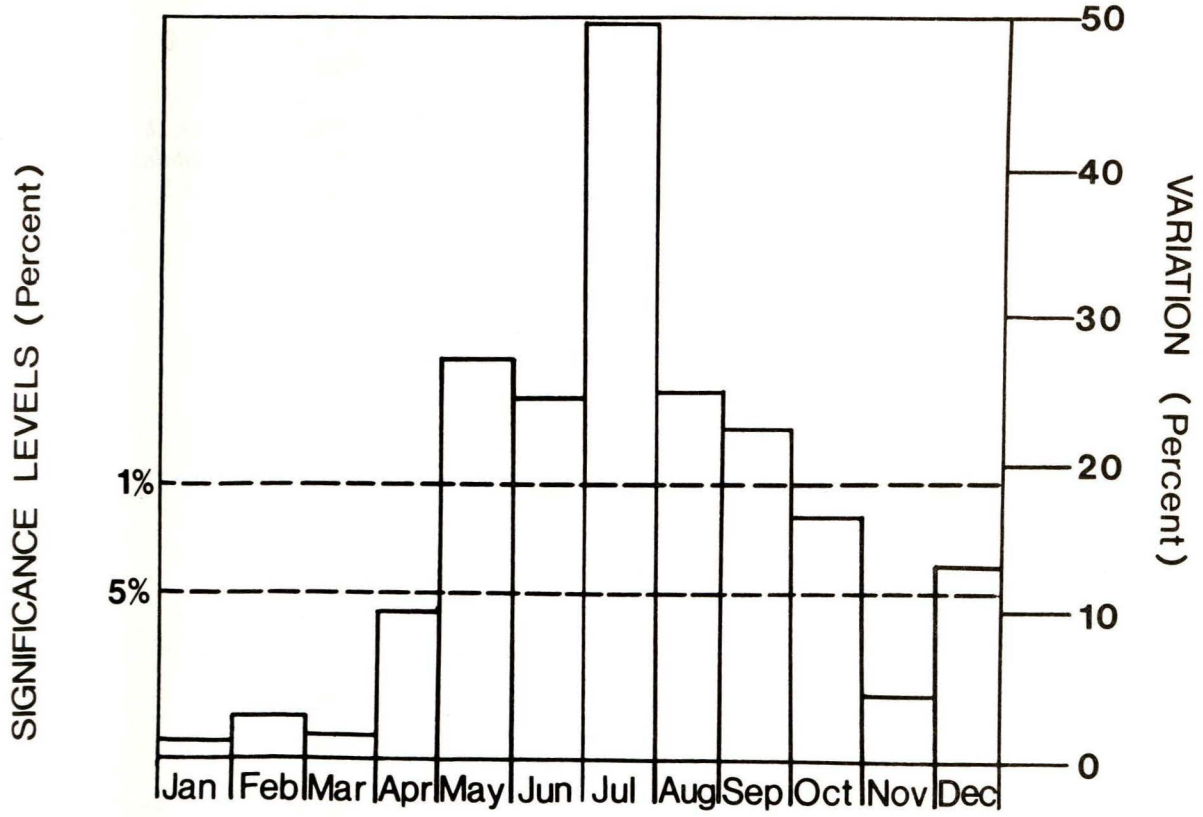

Figure 5.—*Percentage of the variation of fire days associated with the Palmer (Drought) Index and related significance levels, Pocono Mountains division. Each set of monthly data, 1943 to 1974, was computed as a coefficient of determination (r^2), i.e., a square of the correlation coefficient. The simple correlation coefficient is a measure of the degree of linear association between two variables, in this case fire days and drought index number.*

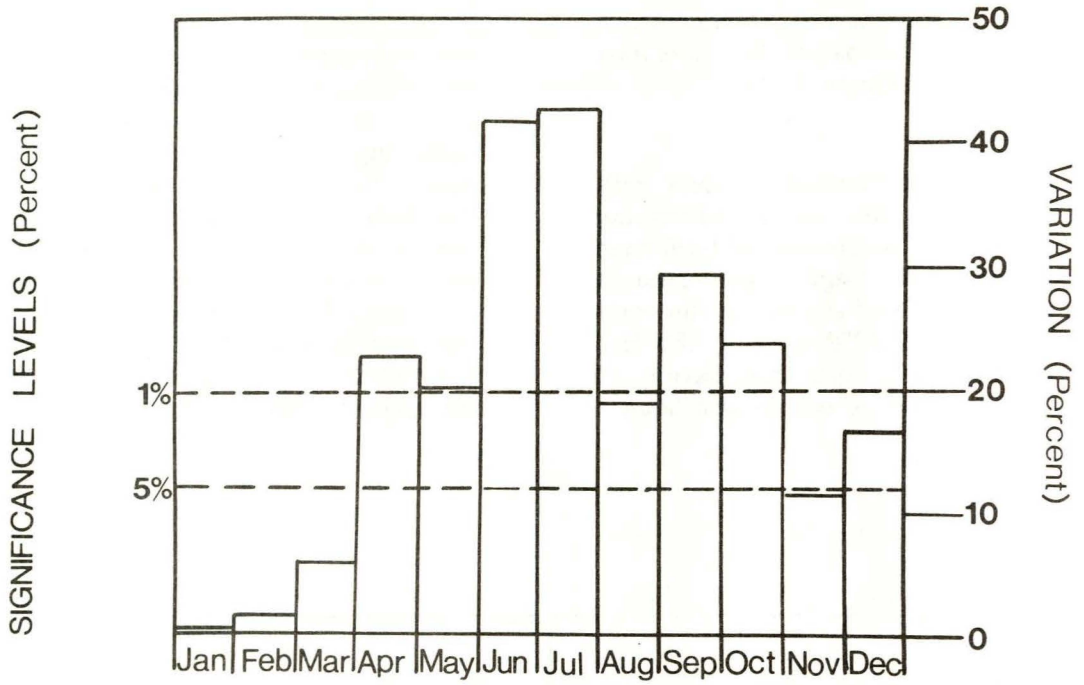

Figure 6.—*Percentage of the variation of cost-to-suppress associated with the Palmer (Drought) Index and related significance levels, Pocono Mountains division. Data were computed by the same method explained in figure 5.*

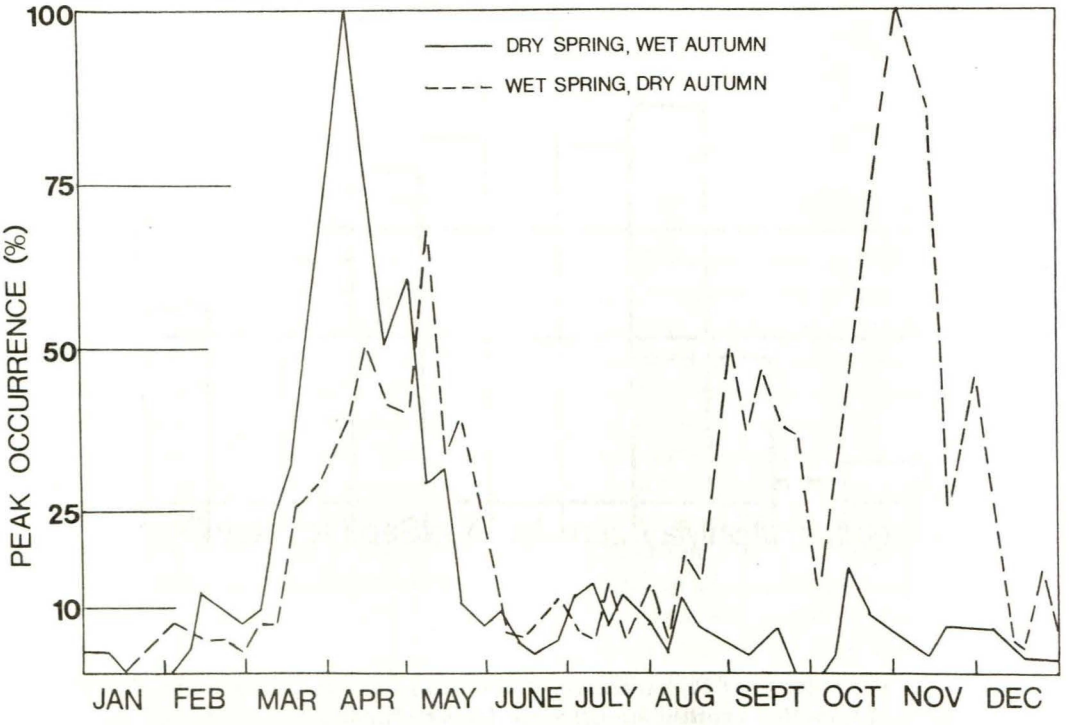

Figure 7.—*Number-of-fires as a percentage of peak occurrence in the middle Susquehanna division during years with:* (a) *dry spring and wet autumn,* (b) *wet spring and dry autumn. Wet-dry division was set at -0.5 on the Palmer Index.*

Table 1.—*Fires by cause category by decade*

(In percent)

Cause	1936-1939	1940-1949	1950-1959	1960-1969	1970-1974
Campfire	64	51	45	13	3
Railroad	12	19	17	15	16
Debris	7	10	16	15	21
Incendiary	6	7	10	23	29
Other	11	13	12	34	17
Equipment					3
Smoking					11

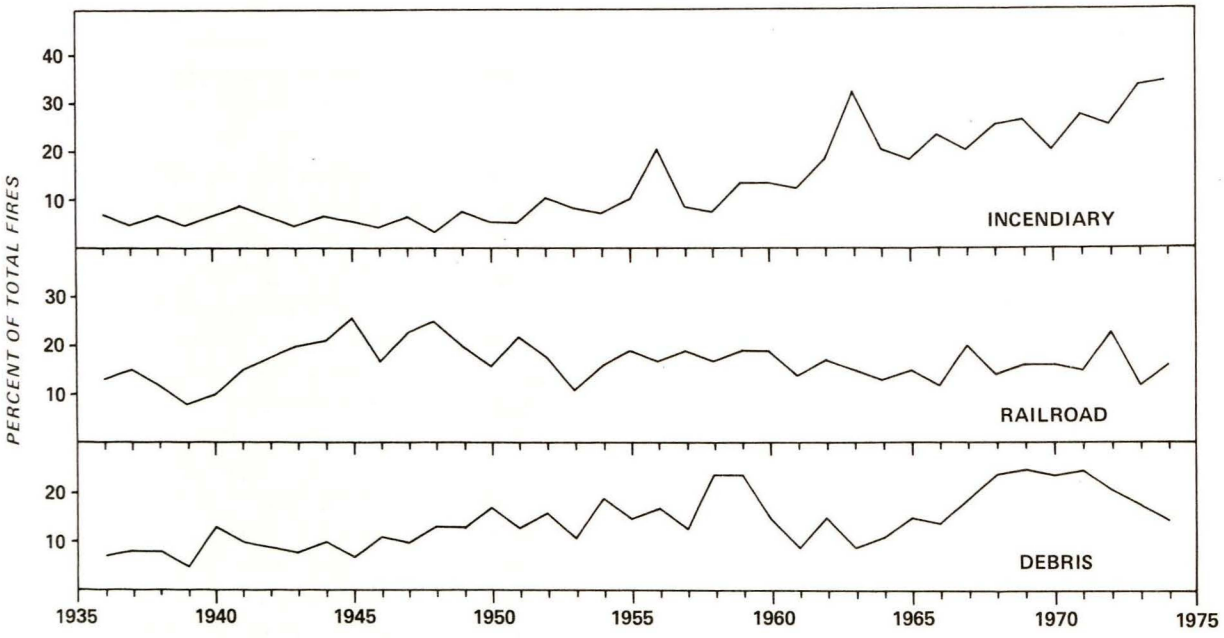

Figure 8.—*Annual percentages of total fires in three cause categories, 1936 to 1974.*

"The railroad fire problem in Pennsylvania is very similar to the problem in other heavily forested States in the Northeast. It is a problem that in spite of some intensive work on the part of fire protection personnel over...many years...does not seem to improve."[2] This 1960's statement is somewhat pessimistic. During the introduction of the diesel locomotive in the late 1940's the State averaged almost 300 railroad fires per year. The yearly average was reduced to 180 fires during the 1950's. The drought of the 1960's plus locomotive deterioration brought railroad fires to 230 fires per year, however this average fell to 134 during the early 1970's. Railroad fires, as a percentage of total fires, peaked in 1945 and have been slowly declining ever since, although railroad fires have had much the same impact on the *total* State fire picture from the early 1950's to present (fig. 8). Twenty-eight railroad companies operate in and through Pennsylvania on 9,357 miles of rights-of-way. But prevention specialist believe that something can be done to prevent railroad fires because many railroads operate without causing forest fires and also because these fires are definitely predictable.

Incendiary fires were an incidental percentage of total fires until the early 1950's (fig. 8). Since then they have become the most important single cause of fires. This phenomenal rise is not unique to Pennsylvania. Incendiarism is now the largest source of man-caused fires over much of the nation. It is also very difficult to prevent incendiary fires. However, the Pennsylvania Division of Forest Fires Protection issued an action plan on incendiarism based on the belief that *all* man-caused fires are preventable.[3]

The monthly Statewide breakdown of almost 6,000 wildfires by cause during the early 1970's shows some interesting features (table 2). Twenty-nine percent of total State fires were attributed to incendiarism, but this percentage doesn't hold through all months of the year. Incendiary fire numbers are near the annual average percent in the spring, but they account for 40 plus percent of total fires in the fall.

Debris fires are largely a spring phenomena, specifically during the month of April, and are probably a result of spring cleanup. To counteract this upsurge, prevention efforts in this cause area should be emphasized each spring.

Railroads are the leading cause of fires in two off-season months, June and August, and are a major problem during late winter and early spring. Because railroads are in fixed locations, the fires begun by trains are in specific locations. This factor leads to some interesting effects. For example, a spring fire along a railroad right-of-way often burns all available fuels, negating autumn fires. However, even with available fuels, autumn railroads fires are usually inconsequential unless a drought conditions has placed the lower vegetation in a state of high hazard.

FIRE ACTIVITY BY DAY-OF-WEEK

Many managers believe that because of certain social patterns, day-of-week is an important consideration in fire-control planning. Weekends, holidays, and other special occasions all produce broad similarities in human activity, which may be related to variations in fire occurrence. Haines *et al.* (1973) reported that forest use is one of the most critical influences on day-of-week fire numbers. For example, they showed that heavy recreational activity increased the number of weekend fires on the Clark National Forest, although there were no such increases on nearby State forests where other forest uses dominated. Certain cause categories display strong preference for specific days of the week (fig. 9). Campfires are a special risk on Saturdays as are fires from children, debris burning, incendiarism, and tobacco smoking. Campfires, children fires, and incendiarism are also high on Sundays. Equipment and railroad fires show little day-of-week preference.

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[2]*Division of Forest Fire Protection. 1968. The railroad forest fire problem in Pennsylvania. Unpublished manuscript on file at the Bureau of Forestry, Department of Environmental Resources, Harrisburg, Pennsylvania.*

[3]*Division of Forest Fire Protection. 1976. A guide to incendiary problem analysis. Unpublished manuscript on file at the Bureau of Forestry, Department of Enviromental Resources, Harrisburg, Pennsylvania.*

Table 2.—*Wildfires by cause as a percent of monthly total for Pennsylvania, 1970 to 1974*

(In percent)

Cause	Jan	Feb	Mar	Apr	May	Ju	Jy	Aug	Sept	Oct	Nov	Dec	Annual total
Incendiary	28	33	31	28	26	30	23	9	40	40	43	25	29
Debris	26	19	22	26	16	7	16	17	9	9	9	16	21
Railroad	19	24	21	15	23	34	8	30	17	8	4	2	16
Children	0	18	9	12	13	12	16	12	12	6	5	3	11
Smoking	6	1	7	10	12	8	25	10	8	15	18	23	11
Other	21	5	10	9	10	9	12	22	14	22	21	31	12
Monthly percentage of annual	1	1	12	51	16	2	1	2	1	6	6	1	100

Percentage of fires on Tuesdays, Wednesdays, and Thursdays are well below the expected and on Saturdays and Sundays are well above. Weekends provide increased leisure time and, therefore, bring increased fire activity in recreation (campfires and smoking fires), property cleanup (debris fires), and general mischief (children and incendiary fires). Railroads, on the other hand, operate routinely through the week.

To see if there were seasonal differences in the number of fires by day-of-week, we separated the data into spring and autumn categories. In the spring the pattern was similar to the total summary (fig. 9) except that railroad fires were significant on Fridays; campfires, debris, and children fires were high on Saturdays; and smoking, children, incendiary, and campfires were high on Sunday. Autumn fires showed little day-of-week variation for any cause category, although, in total, Saturdays showed a significantly higher incidence of fire.

We also examined large fire (more than 10 acres) data by cause for day-of-week but found no significant patterns. Large fires are apparently determined by random weather events and the success of initial attack.

A further analysis of fires by day-of-week by geographic area showed strongest activity centered in the Lower Susquehanna and the South Central Mountains on Saturdays. Less active areas of high Saturday fire activity in the northern half of the Northwest Plateau as well as other scattered areas also appeared.

THE MULTIPLE-FIRE DAY

When fires are infrequent, fire management efforts should be concentrated on predicting days with high probability of a fire. When fires are numerous, management efforts should be concentrated on predicting the number of fires that will occur each day. Examining the number of days having at least one fire (fire-days) and the number of fires per fire-day can provide managers with useful work-load information. We tabulated the number, man-hours to control, and cost data from eight counties in the Scranton area on the basis of fires per fire-day. Most of this more than 2-million-acre area is in the Pocono Mountains Climatic Division (fig.2). One fourth of the days of the year had at least one fire, but during the two major months of the spring fire season, April and May, the area averaged fires on nearly half of the days.

Multiple-fires call for skillful dispatching of fire fighters and equipment plus good communications. The decisions involved with the proper allocation and sudden mobilization of people and equipment necessary to fight large numbers of near simultaneous ignitions are vital. To help make the right decisions, the average number of man-hours required to control fires were computed for days having different numbers of fires per fire-day (fig. 10).

Roughly 8 to 10 man-hours were required to control the average fire when one to five fires occurred on the same day. When six or more fires

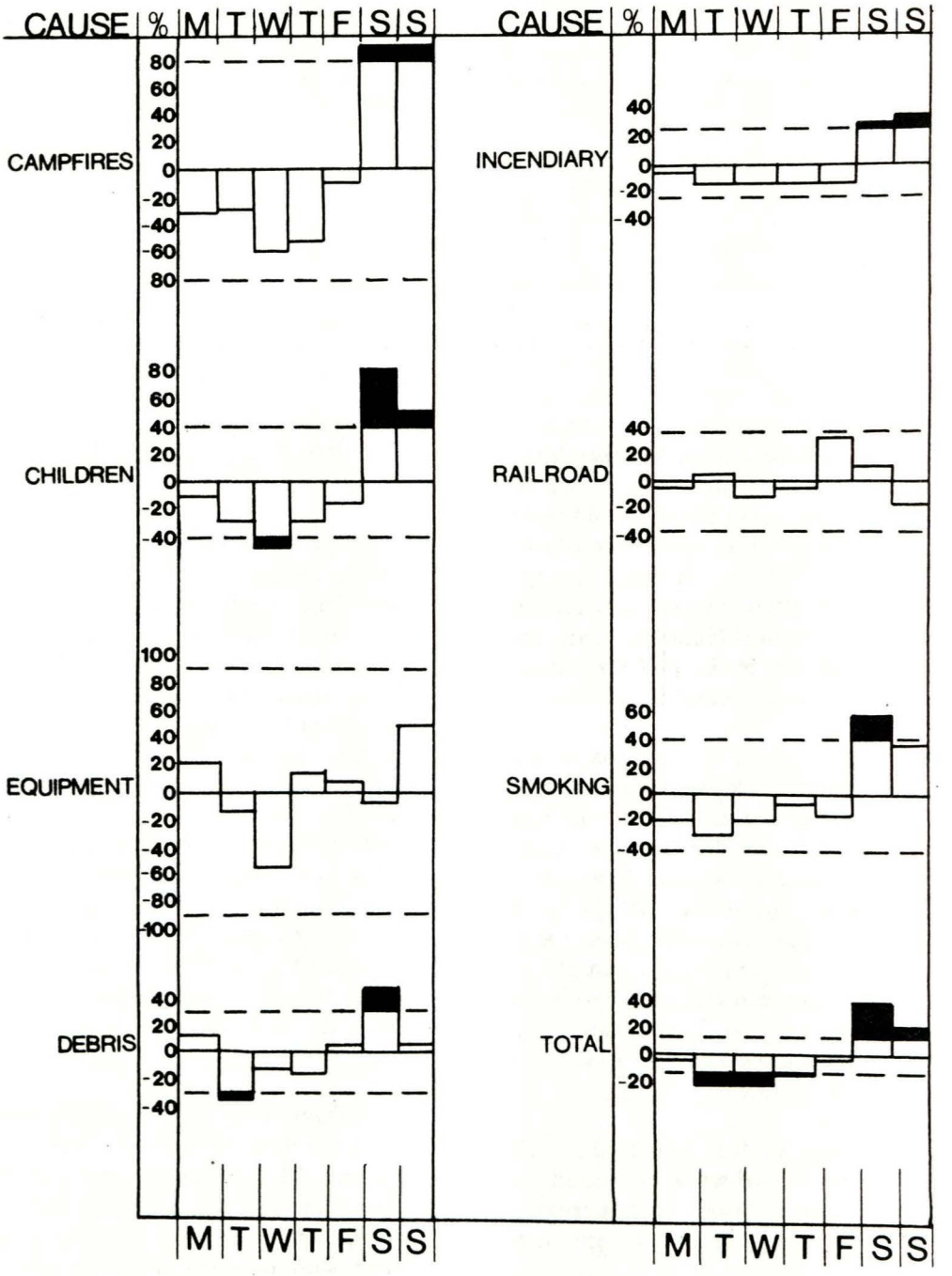
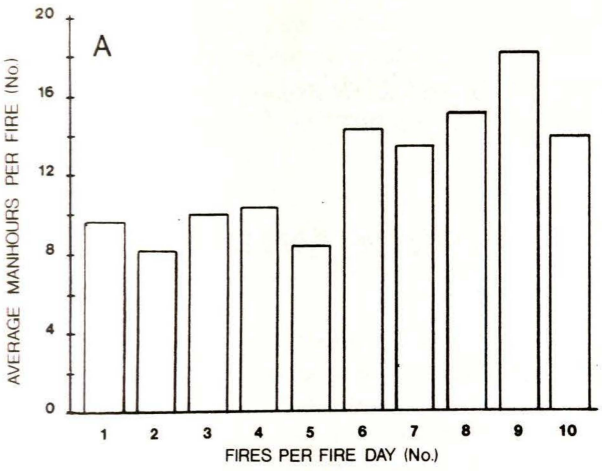
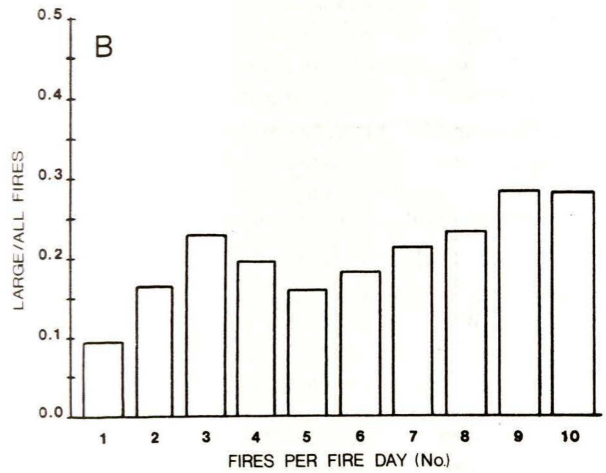


Figure 9.—*Pennsylvania day-of-week fires by cause category, 1970 to 1974. Data are presented as a percentage departure from expected number of fires for each day-of-week. Solid portions of bars show a significant difference at the 0.01 level.*





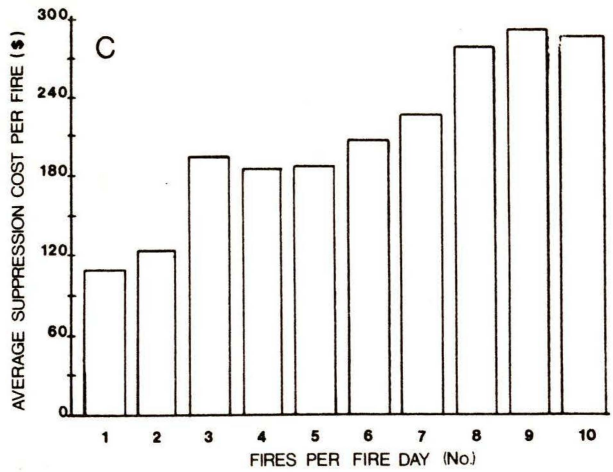


Figure 10.—*Three measures of fire activity based on fires per fire day, Pocono Mountains division, 1962 to 1971:* (A) *number of man-hours required per fire as related to the number of fires per fire day,* (*B*) *number of large fires as related to the number of fires per fire day, and* (*C*) *average suppression cost per fire as related to number of fires per fire day.*

occured on the same day, the number of man-hours to control jumps to 13 to 18. There are two reasons for this. First, increased fires per fire-day reflect increased weather severity, and consequently more control difficulty. Second, manpower resources are exhaustible. As the number of fires increases, there are fewer people available to fight each one. Therefore, the insufficient force present at each fire requires a greater total suppression effort because delays in initial attack contribute to increased control time.

Rapid initial attack with adequate manpower and equipment is often the difference between a small or large fire. We can see this relation when we examine the ratio of large fires (more than 10 acres) to all fires as a function of fires per fire day (fig. 10b). On days when one fire occurred, only one of 10 had a large fire. This ratio increased dramatically as more fires started. On days with nine or more fires, an average of 3 was large.

Along with the large fire and manpower problem, suppression cost per fire increased as fires per day increased (fig. 10c). The cost more than doubled between 1 or 2 fires per day versus 8, 9, or 10 fires per day. The manhour profile showed a dramatic difference at five or less fires per day compared to the cases with six or more fires per day. This probably was the point at which the first line of defense was totally committed and secondary forces had to be mobilized.

The concept of the multiple-fire day has a number of planning applications. During a 10-year period with both drought and nondrought seasons (1962-1971) in the Pocono Mountains, 31 percent of the fires and 61 percent of the acreage burned occurred on only 2 percent of the total days—10 percent of the fire days. These are almost the same percentages Haines *et al.* (1973) found in a similar study in Missouri. So, major fire control activity is usually concentrated in a short time span as shown by the following statistics compiled for the Pocono Mountains (fig. 11):

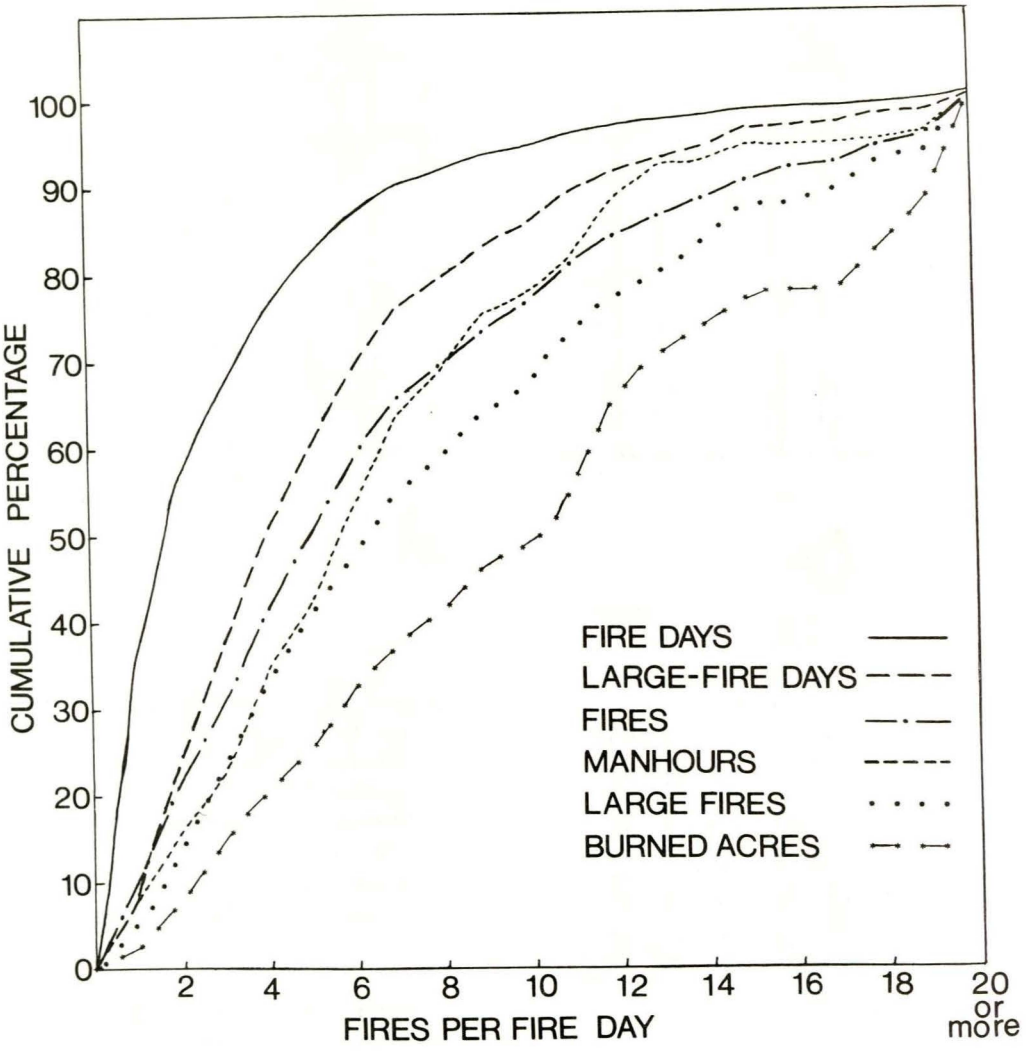


Figure 11.—*Cumulative percent of six measures of fire activity relative to the number of fires per fire day, Pocono Mountains division. Based on 865 fire days with 3,000 wildfires.*

1. Slightly more than half of all fire days had two or more fires.

2. Half of all large-fires days occurred on days when there were four or more fires.

3. Half of all fires occurred on days when there were five or more fires.

4. Half of all man-hours to control were spent on days when there were five or more fires.

5. Half of all large fires occurred on days when there were six or more fires.

6. Half of the burned acreage occurred on days when there were eight or more fires.

Thus, most of the fire control job is compressed into a small number of days of intense activity. Unfortunately, there is no long-term forecast that tells which days will bring high fire activity. Short-term predictions (12 to 36 hours) are presently the best that can be made because fire activity is highly dependent on immediate weather.

One especially important factor when multiple fires are common is rapid initial attack which leads

to increased speed of control. Suppression personnel and equipment cannot be tied up on one fire for a long period because they must be ready to handle other fires. Optimum size of crew and amount of equipment, consequently, are critical considerations.

FIRE CLIMATOLOGY

Fire Danger is a function of the season, a number of weather elements, fuel availability, and human activity. The numerical integration of these factors form the basis for the National Fire Danger Rating System (Deeming *et al.* 1977). This System gives the fire manager an indication of lightning and man-caused risk, the possibility of fire ignition and spread, and the potential energy release rate. Meteorological elements are highly significant in determining these danger components. Therefore, we tabulated a Pennsylvania fire climatology for the principal elements and also for resultant fuel moistures (tables 3-8). Data were taken from Scranton weather records, but the results should apply to most of the State. These data can be used to indicate the climatic probability of being within the bounds of a burning prescription during a given month.

Pennsylvania's temperature range is 0°F to 100°F. The summers are warm—the average is 68°F along Lake Erie to 74°F in southeastern counties. The monthly temperature trends (table 3) show a rapid increase during the spring fire season with 50 percent of the early afternoon readings at or above the upper 30's in March, then increasing into and above the low 50's in April. By April temperatures in the 70's are common. From May to October daily temperatures are usually high enough to support intense fire but other factors, mainly lush lower vegetation and the full canopy of hardwood trees, inhibit flammability. By the autumn fire season the 50th percentile of early afternoon temperatures again drops into the 50's. By late November colder afternoon tempertures coupled with shorter days offer little support for burning.

The annual relative humidity values show a different trend (table 4). Values at the 50th percentile are highest in December, drop off rapidly during the next 4 months, and are lowest in April. During that month half of the early afternoon relative humidities are at 40 percent or below. This phenomenon has a decided impact on increased severity of the spring fire season because relative humidity affects all components of fire danger.

Windspeed is another highly important meteorological element affecting fire. As well as influencing fire spread, the wind affects the drying rate of fuels and maintains the fire in level terrain. Without a supporting wind there will have been a fire, but not necessarily a fire requiring suppression action. For example, on a calm afternoon fire will spread slowly through an area of leaves and may not be able to maintain itself. On a windy day, however, wind-driven, rolling leaves can quickly scatter fire over a wide area.

A Statewide study of windspeed by 10-day periods during the critical months of March, April, and May showed strongest winds occurring April 1 through April 10.[4] The northwest quadrant of Pennsylvania had the strongest observed windspeeds.

Our data indicate a small but important variation of the 50th percentile of windspeed for the year (table 5). During April, the peak of the spring fire season, the wind is 2 or 3 mph stronger than during the rest of the fire period. Much the same pattern occurs when we examine the windspeeds at the 95th percentile. Higher windspeeds during April, combined with the yearly low relative humidities, increase fire danger. Furthermore, higher windspeeds may make it unsafe for aircraft to fly surveillance flights so the time is lengthened between fire start, detection, and initial attack. And of equal importance, aircraft suppression activities are also affected. So, higher windspeed during April is a major reason why it is Pennsylvania's worst fire month.

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[4]*Sylvern, B.L. 1977. A cumulative frequency distribution of the windspeed throughout Pennsylvania. Unpublished manuscript on file at the NOAA Weather Service Forecast Office, Philadelphia, Pennsylvania.*

Table 3.—*Frequency of temperature values, Scranton, Pennsylvania, 13:00 e.s.t., 1962-1971 (Line separates values at or above a cumulative level of 50 percent)*

(In percent of days in month and cumulative percentage)

Month	Temperatures (°F)															
	≤20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	80-84	85-89	90-94	95-99
January	37	17	17	19	7	1	1	(1)	0	(1)	--	--	--	--	--	--
	37	54	71	90	97	98	99	100	100	100	--	--	--	--	--	--
February	28	20	24	16	8	2	1	1	--	--	--	--	--	--	--	--
	28	48	72	88	96	98	99	100	--	--	--	--	--	--	--	--
March	5	8	14	24	20	10	9	4	3	1	1	1	--	--	--	--
	5	13	27	51	71	81	90	94	97	98	99	100	--	--	--	--
April	--	--	1	6	12	18	15	16	13	8	4	3	2	1	--	--
	--	--	1	7	19	37	52	68	81	89	93	97	99	100	--	--
May	--	--	--	1	1	4	7	13	17	18	17	13	5	3	1	--
	--	--	--	1	2	6	13	26	43	61	78	91	96	99	100	--
June	--	--	--	--	--	--	1	3	8	15	16	19	23	13	2	--
	--	--	--	--	--	--	1	4	12	27	43	62	85	98	100	--
July	--	--	--	--	--	--	--	(1)	0	7	16	26	28	17	5	1
	--	--	--	--	--	--	--	(1)	(1)	7	23	49	77	94	99	100
August	--	--	--	--	--	--	--	--	5	8	20	30	28	9	1	--
	--	--	--	--	--	--	--	--	5	13	33	63	91	99	100	--
September	--	--	--	--	--	1	3	11	13	16	24	17	11	2	1	--
	--	--	--	--	--	1	4	15	28	45	69	86	97	99	100	--
October	--	--	(1)	2	5	10	12	24	68	15	11	5	1	--	--	--
	--	--	(1)	3	7	17	29	53	68	83	94	99	100	--	--	--
November	(1)	4	8	17	22	19	14	10	4	2	(1)	--	--	--	--	--
	(1)	4	12	29	51	70	84	94	98	100	100	--	--	--	--	--
December	22	19	20	15	12	6	3	2	(1)	(1)	--	--	--	--	--	--
	22	41	61	76	88	94	97	99	100	100	--	--	--	--	--	--

[1]Less than 0.5 percent.

Table 4.—*Frequency of relative humidity values, Scranton, Pennsylvania 13:00 e.s.t., 1962-1971 (Line separates values at or above a cumulative level of 50 percent)*

(In percent of days in month and cumulative percentage)

Month	Relative Humidity (Percent)														
	≤ 14	15-19	20-24	25-29	30-34	35-39	40-44	45-49	50-54	55-59	60-64	65-69	70-74	75-79	≥80
January	2	1	2	1	1	3	5	4	9	10	12	15	8	7	20
	2	3	5	6	7	10	15	19	28	38	50	65	73	80	100
February	1	1	1	1	3	4	5	10	8	12	12	8	6	5	23
	1	2	3	4	7	11	16	26	34	46	58	66	72	77	100
March	1	(1)	1	4	6	10	9	11	7	10	8	5	6	5	17
	1	1	2	6	12	22	31	42	49	59	67	72	78	83	100
April	--	2	8	8	12	11	11	7	7	5	3	3	4	4	15
	--	2	10	18	30	41	52	59	66	71	74	77	81	85	100
May	(1)	1	2	5	10	14	12	11	7	7	8	3	4	3	13
	(1)	1	3	8	18	32	44	55	62	69	77	80	84	87	100
June	(1)	(1)	(1)	--	7	9	11	16	5	11	9	10	7	6	9
	--	--	--	--	7	16	27	43	48	59	68	78	85	91	100
July	--	--	--	3	5	9	9	12	13	12	8	11	7	4	7
	--	--	--	3	8	17	26	38	51	63	71	82	89	93	100
August	--	--	--	--	1	4	9	14	17	15	7	12	7	7	7
	--	--	--	--	1	5	14	28	45	60	67	79	86	93	100
September	--	--	--	2	2	4	5	11	15	10	14	10	4	7	16
	--	--	--	2	4	8	13	24	39	49	63	73	77	84	100
October	--	--	(1)	1	5	7	8	13	8	14	11	8	5	5	15
	--	--	(1)	1	6	13	21	34	42	56	67	75	80	85	100
November	--	--	(1)	1	2	4	6	9	7	12	11	6	6	7	29
	--	--	(1)	1	3	7	13	22	29	41	52	58	64	71	100
December	(1)	(1)	1	1	1	1	2	5	7	11	13	11	8	10	29
	(1)	(1)	1	2	3	4	6	11	18	29	42	53	61	71	100

[1]Less than 0.5 percent.

Table 5.—*Frequency of windspeeds, Scranton, Pennsylvania, 13:00 e.s.t., 1962-1971 (Vertical line separates values at or above a cumulative level of 50 percent)*

(In percent of days in month and cumulative percentage)

Month	Wind speeds (m.p.h.)											
	0-3	4-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	22-23	≥25
January	14	10	7	14	19	16	6	8	2	2	(1)	2
	14	24	31	45	64	80	86	94	96	98	98	100
February	14	11	5	14	15	16	8	9	4	2	1	1
	14	25	30	44	59	75	83	92	96	98	99	100
March	5	14	5	13	17	18	7	13	5	1	1	(1)
	5	19	24	37	54	72	79	92	97	98	99	100
April	3	11	6	13	14	21	5	14	8	3	(1)	2
	3	14	20	33	47	68	73	87	95	98	98	100
May	3	10	6	17	20	20	7	12	3	1	1	--
	3	13	19	36	56	76	83	95	98	99	100	--
June	3	15	8	27	22	15	3	5	2	--	--	--
	3	18	26	53	75	90	93	98	100	--	--	--
July	4	16	11	19	24	12	6	6	2	--	--	--
	4	20	31	50	74	86	92	98	100	--	--	--
August	3	13	11	26	21	19	3	4	--	--	--	--
	3	16	27	53	74	93	96	100	--	--	--	--
September	6	14	12	19	25	13	5	4	1	1	--	--
	6	20	32	51	76	89	94	98	99	100	--	--
October	9	14	8	20	19	15	5	7	2	1	--	--
	9	23	31	51	70	85	90	97	99	100	--	--
November	10	16	7	17	14	17	8	8	1	2	(1)	--
	10	26	33	50	64	81	89	97	98	100	100	--
December	11	15	5	17	17	11	5	12	3	2	1	1
	11	26	31	48	65	76	81	93	96	98	99	100

[1]Less than 0.5 percent.

Table 6.—*Days since last 0.10 inches or more of precipitation Scranton, Pennsylvania, 1962-1971 (Vertical line separates values at or above a cumulative level of 50 percent)*

(Expressed as number of events, percent of monthly total, and cumulative percentage)

Month	Days since last precipitation event ≥ 0.10 inch																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
January	1	5	1	2	3	3	4	2	2	1	0	2	1	0	0	1	0	0	0	0
	3	17	3	7	10	10	13	7	7	3	0	7	3	0	0	3	0	0	0	7
	3	20	23	30	40	50	63	70	77	80	80	87	90	90	90	93	93	93	93	100
February	3	5	3	6	3	3	1	1	2	2	1	0	2	0	0	0	1	0	0	1
	8	15	9	18	9	9	3	3	6	6	3	0	6	0	0	0	3	0	0	2
	8	23	32	50	59	68	71	74	80	86	89	89	95	95	95	95	98	98	98	100
March	4	5	5	4	2	3	4	1	1	2	2	1	0	1	0	1	0	0	0	3
	10	13	13	10	5	8	10	3	2	5	5	3	0	3	0	2	0	0	0	8
	10	23	36	46	51	59	69	72	74	79	84	87	87	90	90	92	92	92	92	100
April	10	10	4	5	2	3	3	2	0	1	0	2	1	0	0	0	1	0	0	3
	21	21	9	11	4	6	6	5	0	2	0	4	2	0	0	0	2	0	0	7
	21	42	51	62	66	72	78	83	83	85	85	89	91	91	91	91	93	93	93	100
May	5	6	9	3	5	3	4	2	1	1	1	1	0	0	0	1	1	--	--	--
	12	14	21	7	11	7	9	5	2	2	3	2	0	0	0	2	3	--	--	--
	12	26	47	54	65	72	81	86	88	90	93	95	95	95	95	97	100	--	--	--
June	5	7	2	4	4	5	2	2	2	2	0	1	0	1	2	1	0	0	1	--
	12	17	5	10	10	12	5	5	5	4	0	2	0	3	5	2	0	0	3	--
	12	29	34	44	54	66	71	76	81	85	85	87	87	90	95	97	97	97	100	--
July	10	7	5	9	3	2	3	3	0	1	3	0	0	0	2	1	0	0	0	1
	20	14	10	18	6	4	6	6	0	2	6	0	0	0	4	2	0	0	0	2
	20	34	44	62	68	72	78	84	84	86	92	92	92	92	96	98	98	98	98	100
August	6	3	6	6	5	2	1	2	0	1	2	2	1	0	1	0	1	0	0	1
	15	7	15	15	13	5	2	5	0	3	5	5	2	0	3	0	2	0	0	3
	15	22	37	52	65	70	72	77	77	80	85	90	92	92	95	95	97	97	97	100
September	3	2	6	4	2	1	2	7	3	1	1	2	1	0	1	0	0	0	0	1
	8	5	16	11	5	3	6	19	8	3	3	5	3	0	2	0	0	0	0	3
	8	13	29	40	45	48	54	73	81	84	87	92	95	95	97	97	97	97	97	100
October	3	3	7	3	5	2	0	0	0	3	1	2	2	0	0	0	1	0	0	1
	9	9	21	9	15	6	0	0	0	9	3	7	6	0	0	0	3	0	0	3
	9	18	39	48	63	69	69	69	69	78	81	88	94	94	94	94	97	97	97	100
November	7	6	2	9	6	1	5	2	0	0	2	1	0	2	0	2	0	0	0	2
	15	13	4	19	13	2	10	4	0	0	5	2	0	4	0	4	0	0	0	5
	15	28	32	51	64	66	76	80	80	80	85	87	87	91	91	95	95	95	95	100
December	5	6	5	5	1	6	4	0	2	0	3	1	2	1	1	0	1	--	--	--
	12	14	12	11	2	14	9	0	5	0	7	2	5	2	2	0	3	--	--	--
	12	26	38	49	51	65	74	74	79	79	86	88	93	95	97	97	100	--	--	--

Table 7.—*Frequency of 1-hour timelag fuel moistures, Scranton, Pennsylvania, 13:00 e.s.t., 1962-1971 (Vertical line separates values at or above a cumulative level of 50 percent)*

Month	Fuel moisture (Percent)																			
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
March	(1)	(1)	2	7	9	14	9	14	11	6	4	2	--	--	--	(1)	--	1	18
	(1)	1	3	10	19	33	43	57	68	74	78	80	80	80	80	81	81	82	100
April	--	2	11	15	17	9	9	6	9	3	5	(1)	--	(1)	(1)	--	--	--	14
	--	2	13	28	45	54	63	69	78	81	86	86	86	86	86	86	86	86	100
May	(1)	1	5	13	18	12	13	9	7	4	3	1	(1)	--	--	--	--	--	13
	(1)	1	6	19	37	49	62	71	78	82	85	86	87	87	87	87	87	87	100
June	--	--	1	8	13	16	16	13	16	4	4	1	(1)	--	(1)	--	--	--	8
	--	--	1	9	22	38	54	67	83	87	91	92	92	92	92	92	92	92	100
July	--	--	3	7	9	20	18	11	16	4	4	(1)	--	--	(1)	--	--	--	7
	--	--	3	10	19	39	57	69	85	89	93	93	93	93	93	93	93	93	100
August	--	--	(1)	2	7	19	22	16	15	7	4	1	(1)	(1)	--	--	--	--	7
	--	--	(1)	2	9	28	50	66	81	88	92	93	93	93	93	93	93	93	100
September	--	--	1	4	6	14	17	16	17	8	2	2	(1)	1	(1)	--	--	1	10
	--	--	1	5	11	25	42	58	75	83	85	87	87	88	89	89	89	90	100
October	--	--	1	5	9	17	15	14	17	6	2	2	1	--	--	(1)	--	--	11
	--	--	1	6	15	32	47	61	78	84	86	88	89	89	89	89	89	89	100
November	--	--	1	1	6	5	13	18	10	14	8	3	--	1	1	(1)	(1)	(1)	18
	--	--	1	2	8	13	26	44	54	68	76	79	79	80	81	81	81	82	100
December	--	--	--	1	1	3	7	14	15	16	5	6	2	1	(1)	(1)	2	--	27
	--	--	--	1	2	5	12	26	41	57	62	68	70	71	71	71	73	73	100

[1]Less than 0.5 percent.

Table 8.—*Frequency of 10-hour timelag fuel moistures, Scranton, Pennsylvania, 13:00 e.s.t., 1962-1971 Vertical line separates values at or above a cumulative level of 50 percent*

Month	Fuel moistures (Percent)																
	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20+
March	(1)	1	2	5	5	10	11	8	11	11	7	5	2	2	1	--	--	19
	(1)	1	3	8	13	23	34	42	53	64	71	76	78	80	81	81	81	100
April	--	3	9	12	12	10	10	7	4	6	6	2	4	(1)	--	(1)	--	14
	--	3	12	24	36	46	56	63	67	73	79	81	85	85	85	86	86	100
May	(1)	1	5	10	11	15	7	12	7	7	5	3	2	1	(1)	--	--	14
	(1)	1	6	16	27	42	49	61	68	75	80	83	85	86	86	86	86	100
June	--	--	1	4	11	11	13	12	12	14	6	3	3	1	1	--	--	8
	--	--	1	5	16	27	40	52	64	78	84	87	90	91	92	92	92	100
July	--	--	2	5	7	12	15	15	8	15	7	3	3	(1)	(1)	--	--	8
	--	--	2	7	14	26	41	56	64	79	86	89	92	92	92	92	92	100
August	--	--	--	1	3	11	15	18	13	15	9	4	2	1	(1)	(1)	(1)	7
	--	--	--	1	4	15	30	48	61	76	85	89	91	92	92	92	93	100
September	--	--	1	3	5	6	13	12	15	14	9	5	2	2	(1)	1	1	11
	--	--	1	4	9	15	28	40	55	69	78	83	85	87	87	88	89	100
October	--	--	1	4	5	10	12	12	14	12	11	4	2	2	(1)	(1)	--	11
	--	--	1	5	10	20	32	44	58	70	81	85	87	89	89	89	89	100
November	--	--	1	1	4	3	5	12	14	9	11	9	7	3	--	(1)	1	19
	--	--	1	2	6	9	14	26	40	49	60	69	76	79	79	79	81	100
December	--	--	--	1	1	1	3	6	12	8	15	13	3	6	2	(1)	(1)	29
	--	--	--	1	2	3	6	12	24	32	47	60	63	69	71	71	71	100

[1]Less than 0.5 percent

Average yearly precipitation in Pennsylvania anges from 36 inches to 48 inches, depending on cation. Precipitation, or the lack of it, is an portant feature of fire weather. Generous mounts will allow rapid growth of low vegetation nd penetrate the dead fuels to inhibit combus-ion. Deficits may cause the low vegetation to cure nd become fine fuels.

We computed a climatological table of days ince last precipitation using 0.10 inch as a hreshold value (table 6). The 10 years examined ncluded both drought and nondrought periods fig. 4). During the critical spring and autumn fire easons rain of at least 0.10 inch occurs at 1- to -day intervals 50 percent of the time. September howed the longest rain-free period. Chances of aving as many as 10 consecutive rain-free days ≥ 0.10 inch) in any month was only 10 to 20 ercent.

Timelag is defined as the time necessary for a uel particle to lose approximately 63 percent of he difference between its initial moisture content and its equilibrium moisture content (Deeming *et al.* 1977). We will discuss two categories of timelag fuels. One hour fuels consist of dead herbaceous plants and roundwood less than 1/4 inch in diameter. Also included in this category is the uppermost layer of litter on the forest floor. Most fires begin in these fuels. Ten-hour fuels consist of dead fuels of roundwood 1/4 to 1 inch in diameter and the layer of litter extending from just below the surface to 3/4 inch below the surface.

The 1-hour timelag fuel moisture is dependent upon the relative humidity and the temperature. The highest moisture contents in these fuels occur in winter (table 7). Average moisture contents at the 50th percentile level are at 8 or 9 percent from March through October except for readings at 7 percent during April.

The 10-hour timelag fuel moisture may be read directly from wooden fuel analogues or may be computed mathematically from maximum-minimum relative humidity and temperature,

duration of precipitation, and hours of daylight. The month-to-month pattern of moisture content is similar to that of the 1-hour fuel (table 8). Highest moisture contents occur in winter. At the 50th percentile level average moisture contents are at 10 or 11 percent from March through October except for readings at 9 percent during April.

SUMMARY

Fire protection is critical in Pennsylvania because more than 60 percent of the total land area is wooded and much of it is capable of timber production. Pennsylvania also has the largest rural population of any State in the country—3.5 million people.

A tabulation of 60 years of State fire records showed a sharp drop in number of fires since World War II. Also, the ratio of large fires to all fires was about 40 percent in the mid-1940's, but steadily lowered so that it is now about 10 percent.

The major fire season begins in mid-March, peaks in April, and ends in mid-June. There is a second, less severe, fire season that begins in early October and ends in late November.

Campfires showed an impressive reduction as a cause of wildfire, from 64 percent of total in the late 1930's to 3 percent today. Incendiarism has increased dramatically.

Grouping the fire activity data by day-of-week showed that campfires were a special risk on Saturdays as were fires from children, debris burning, incendiarism, and tobacco smoking. Campfires, children fires, and incendiarism were also high on Sundays.

The multiple-fire day is highly indicative of the dynamics of fire suppression. One-fourth of the days of the year had at least one fire in the Pocono Mountains, but during April and May the area averaged fires on nearly half of the days. One-third of the fire days produced one fire; two-thirds of the fire days had three fires or less; the remainder of the fire days had from 4 to 28 fires. Roughly 9 to 10 man-hours were required to control the average fire when one to five fires occurred on the same day. There was a sudden jump to 13 to 18 man-hours per fire when six or more fires occurred on the same day.

The fire climatology of the State follows pattern seen throughout much of the northeastern United States. The major impact of weather elements occurs during April, the peak of the fire season.

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Haines, Donald A., William A. Main, and Eugene F. McNamara. 1978. Forest fires in Pennsylvania. U.S. Dep. Agric. For. Serv. Res. Pap. NC-158, 20 p. North Cent. For. Exp. Stn., St. Paul, Minnesota.

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